Beam-Plasma Interactions in the Marshall Magnetic Mirror

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Outline of Presentation

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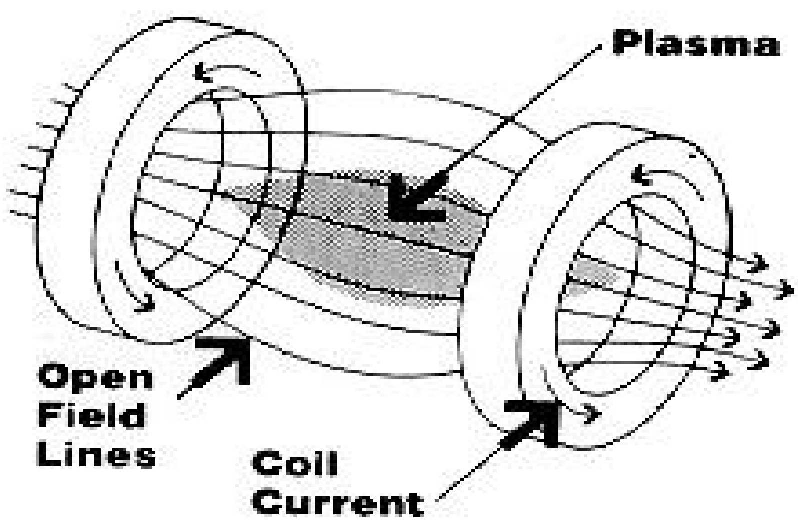
  - Existing Devices
- **Marshall Magnetic Mirror**
  - Magnetic Mirrors
  - Description of M3 Device
- **Beam-Plasma Experiment**
  - Experiment Description
  - Plasma Parameters
- **Diagnostics**
- **Initial Data**
- **Future Experiments and Collaborations**

Plasma Propulsion

- **High temperature and density gas (plasma) is ejected at high velocity from a containment device thereby creating thrust.**
  - Require density > 10^{17} m^{-3}; Require temperature > 100 eV
- **Magnetic fields are used to contain the plasma and ultimately to form a magnetic nozzle.**
- **Cylindrical magnetic field geometries are a natural choice for propulsion.**
- **Plasma propulsion is expected to yield high Specific Impulse (Isp).**
  - Isp scales with temperature of propellant
- **Demonstration Device is being built within NASA**
  - VASMIR device at JSC is almost at demonstration phase
  - On-orbit requirements have been plotted

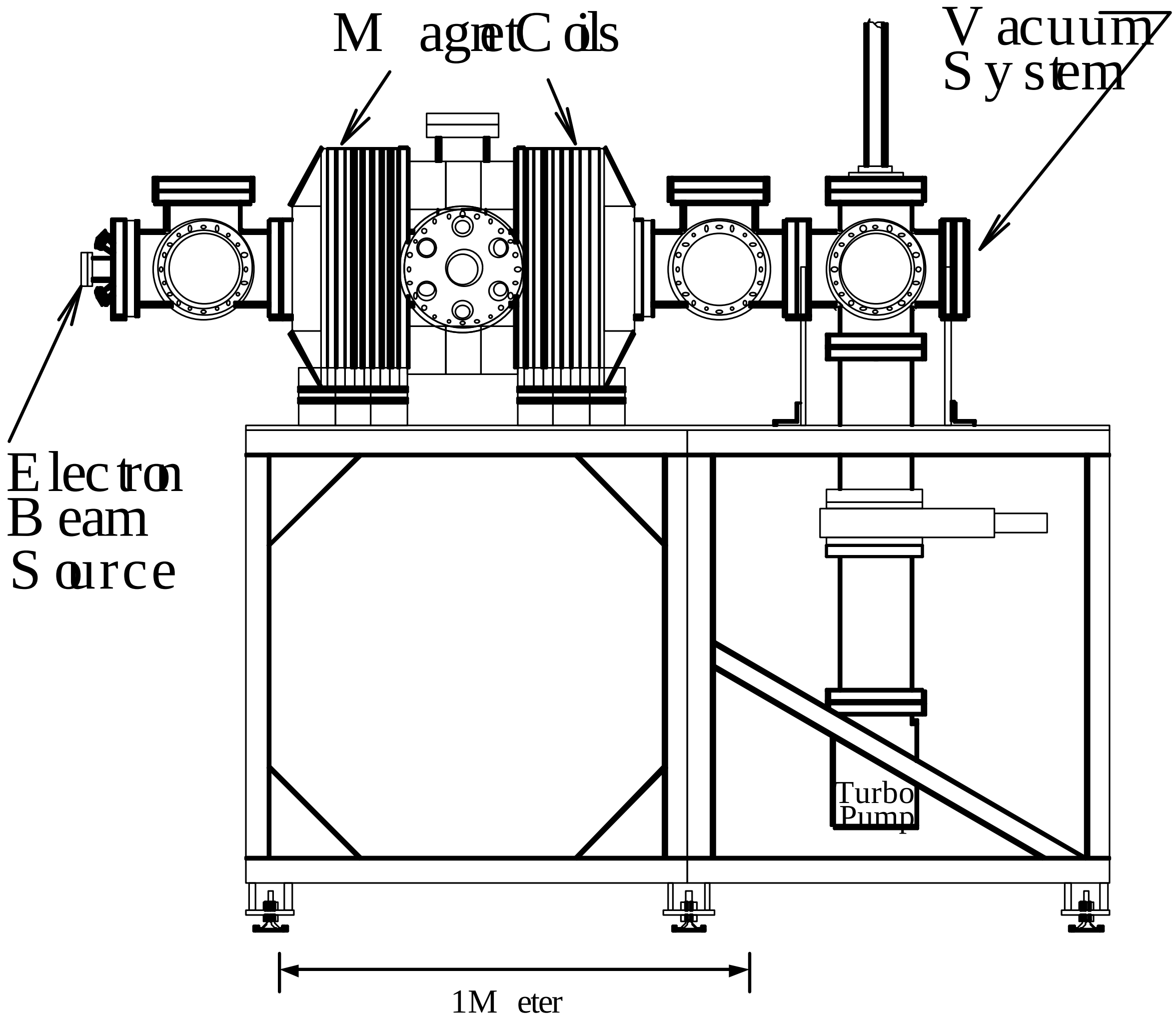
Magnetic Mirrors

- **Magnetic mirrors are common to most plasma propulsion designs.**

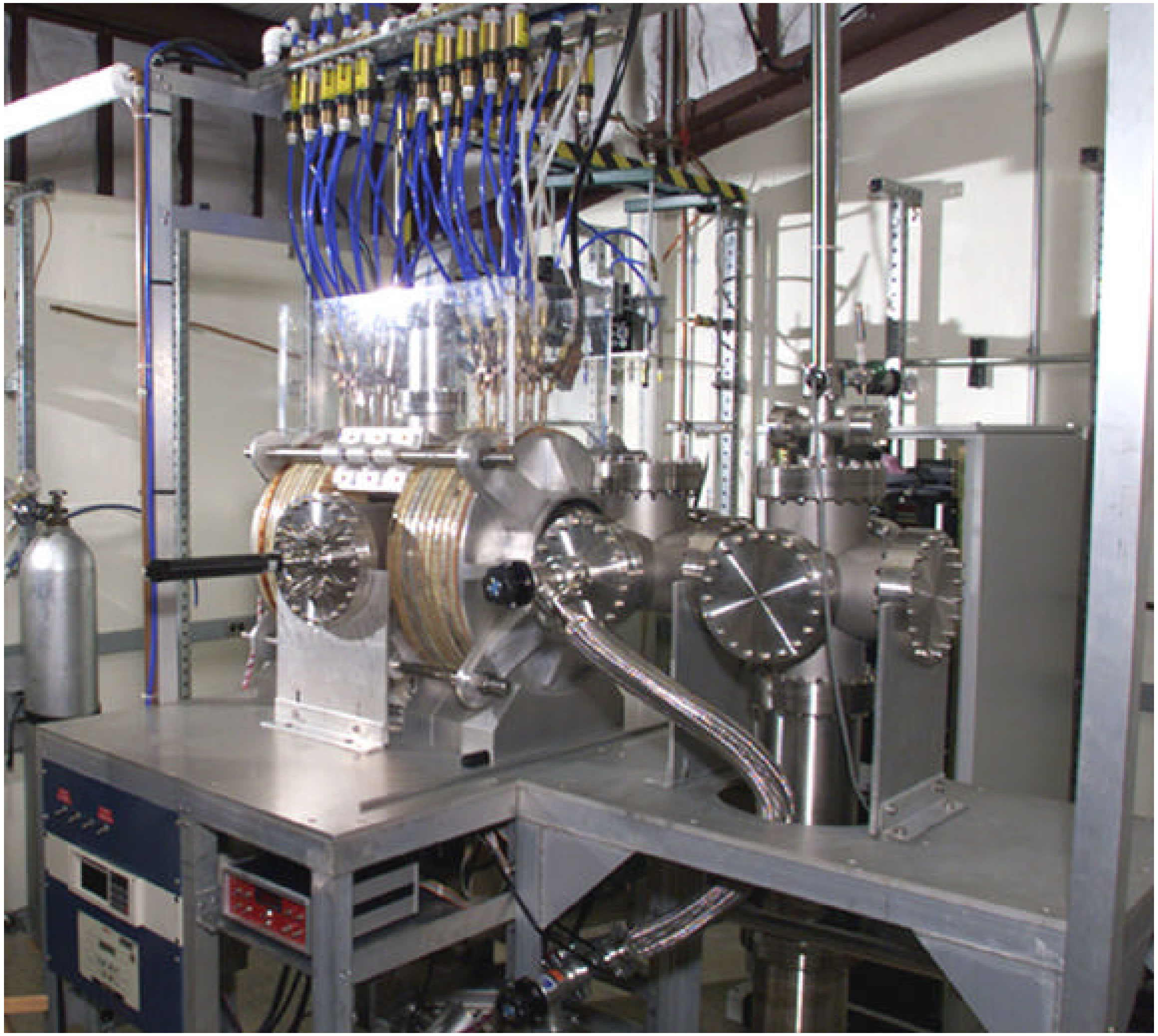


Drawing from Lawrence Livermore National Lab Fusion Education Web Site
(http://education.llnl.gov/lasers/fusion/blue15.html)

Marshall Magnetic Mirror Layout

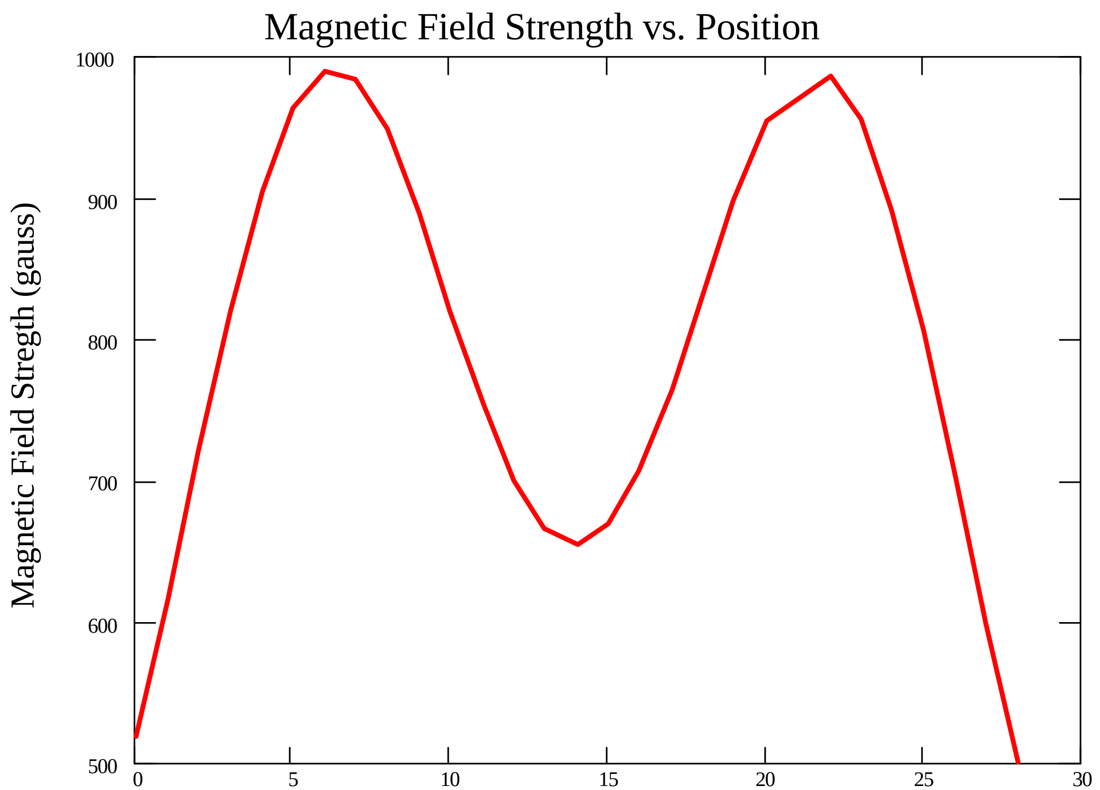


Marshall Magnetic Mirror



Plot of Magnetic Field Strength in the M3 Device

- **Magnetic field strength as a function of position (Lengthwise)**



Scan Through Length

100 Amps Through Coils

(Resistance = 0.44 ohms)

B-field:

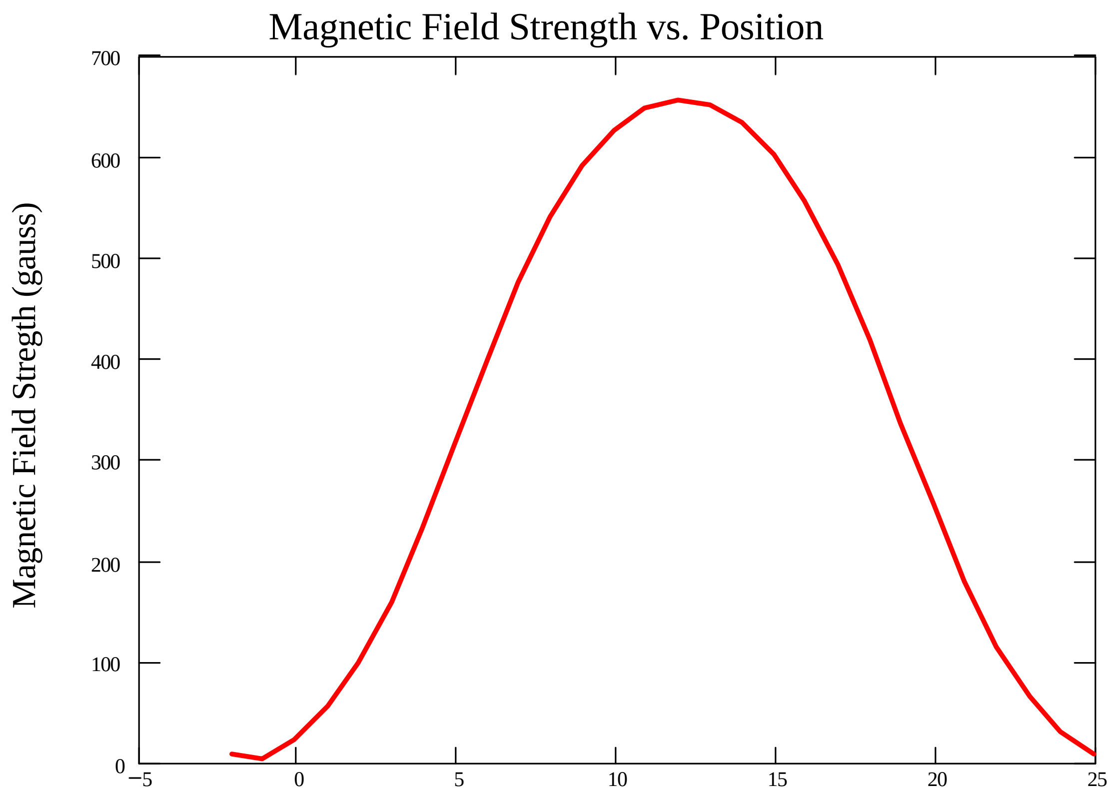
Max. = 989 Gauss

Min. = 655 Gauss

Ratio = 1.5

Plot of Magnetic Field Strength in the M3 Device

- **Magnetic field strength as a function of position (Radial)**



Scan Through Diameter

100 Amps Through Coils

(Resistance = 0.44 ohms)

B-field:

Max. = 657 Gauss

M3 Description and Support Equipment

- **Magnet Coils**
  - Each magnet is composed of 9 individual coils
  - Total number of turns (series) is: 33 turns per coil x 9 Coils x 2 Sets = 594 turns
  - Cylindrical Vacuum Chamber
- **Magnet Power Supply System**
  - Three (3) DC power supplies; 310 amps, 32 volts – series operation
  - Maximum Magnetic Field on axis is: 1,000 Gauss
- **Microwave Power Supply System**
  - 2 kW CW source, 2.45 GHz
- **Electron Beam System**
  - Hollow Cathode System (EPL Model HCPEE 500)
  - 50 amps continuous rating; 100 amps for 30 secs
  - Capacitor Bank supply will allow 400-500 amps for 200 milliseconds
- **Gas Feed System**
  - Use Argon, Xenon, and Hydrogen gas
  - Mass flow controller: 0.5 sccm to 10 sccm

Beam-Plasma Experiment

- **Conduct an experimental study of the interaction of an electron beam with a plasma.**
- **Determine feasibility of using an electron beam to increase plasma density and temperature for future plasma propulsion devices**
- **Initial plasma density limited by cut-off density**
  - For 2.45 GHz, Cut-off density = 1×10^{11} cm^{-3}
- **Optimize the power coupling between the electron beam and plasma by varying several parameters.**
  - Neutral gas type and density
  - Magnetic field strength and configuration (trim coils)
  - Microwave power input to plasma
  - Beam energy and current
- **Compare results with theory and modeling.**
  - Plasma wave excitation/instabilities
  - Use beam-plasma computer codes (existing)

Diagnostics

- **Langmuir Probes**
  - Scan inside magnetic mirror and downstream
  - Look at relative changes in electron temperature and plasma density with and without beam injection
- **Mach Probes**
  - Measure exit velocities outside of mirror
- **Pearson Coils**
  - Determine electron beam pulse parameters
- **Microwave Interferometer(s)**
  - Measure plasma density with and without e-beam injection
  - Two interferometers existing:
    - 10 GHz (X-band) Interferometer
    - 60 GHz (V-band) Interferometer
- **Data Acquisition**
  - Digital Oscilloscopes (8 channels) 400 MHz
  - PXI Modular DAQ System with embedded controller
    - 4 oscilloscope channels (100 MHz)
    - Directly integrated into Labview System/PC

Future Work

- **Increase electron beam current by utilizing existing capacitor bank power supply**
- **Utilize new 2000 amp power supply to operate at higher magnetic fields (perhaps 2 kgauss).**
- **Have partnered with Oak Ridge National Lab to increase diagnostic capabilities (improvements to microwave interferometers).**
- **Will be testing Submicron Retarding Field Energy Analyzer (also in partnership with Oak Ridge).**
- **Investigate the use of a helicon plasma source to achieve high initial plasma density**